CBE 30357
Fall 2017
Homework #8
Due 11/21/17 (or later)

1. Examination of the Engineering Bernoulli equation.

The Engineering Bernoulli Equation, which will be derived from the equation of energy conservation, is:

$$\left(\frac{<v_2>^2}{2} + gh_2 + \frac{P_2}{\rho}\right) - \left(\frac{<v_1>^2}{2} + gh_1 + \frac{P_1}{\rho}\right) = \delta W_s - l_v .$$

In this form the only restriction is that density is kept constant. The left side terms consider the "state" of the system at two locations, which must be connected along a path of the flow. (If the fluid is not flowing, then the two locations need to be connected with continuous quiescent fluid.)

The right side terms give information about the power input, δW_s, and what rate of conversion of mechanical energy to heat, l_v, is occurring.

i. Compare the Engineering Bernoulli Equation (aka "EBE") to the full conservation of energy equation and determine the exact relation between δW_s and $\dot{W}_s$

ii. Compare the Engineering Bernoulli Equation (aka "EBE") to the full conservation to determine the physical meaning of the l_v and explain why it must always be positive.

iii. Use the EBE to calculate the pressure difference between the surface of a pool of water and the value 4m under the water?

iv. Consider wind blowing from the South through Debartolo quad at 35 mph. How much higher than nominal atmospheric pressure is the (maximum) pressure at the south wall of Fitzpatrick Hall?

2. MEA solution flow in Kensington, London, UK.

Imperial College has a “pilot plant”, that, as one perceptive student has pointed out, doesn’t really do anything because the carbon dioxide that is absorbed … in the absorber, is stripped back out in the stripper and … recycled back to the absorber[1].

The “J100 Lean Solvent Pump” pumps the “lean solvent” (25 wt% monoethanolamine in water solution) from the lower level of the plant, through (for the purposes of this problem) 15 elbows, 5 couplings and lets say 5 “area restrictions” (for various measurements) where the area is reduced by 20% before returning to the nominal pipe size. There is about 70 feet of piping which looks to be about 1.5 in stainless steel (as in some standard, presumably schedule 40, pipe size.)[2] The inlet to the absorber is about 35 feet above the level of the pump. However, I am sure that that any of the students who were there would tell you that they were warned not to let the “surge” tank level get too low. So let’s say that there are 4 feet of MEA-solution in the tank for the lower flow rate and 2 feet of solution for the higher flow rate. — why would this be different?)

Find the pumping power (from the variable speed, positive displacement, J100 Lean solvent pump) if the flow rate of MEA is

a. 700 kg/hour

b. 1100 kg/hour

Data for MEA in water are available in a document in the References folder on Sakai.

Please do the calculations for both 25 C and 50 C.

c. Determine the fraction of “losses” that are due to the fittings?

d. Determine the fraction of “losses" that are due to pipe friction?

e. Determine the equivalent fraction of “losses” due to the height change.

f. What is the advantage of a variable speed, positive-displacement pump as opposed to a more common centrifugal pump that runs at constant speed (as determined but electricity frequency and configuration)?

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[1] A careful analysis would indicate that it takes perfectly good steam, removes some heat to produce condensate, perfectly good electricity that must end up as waste heat and probably warms up some chilled process water. Perhaps, the net benefit is some student learning!

[2] Sorry, I do “English System” when I am describing devices in that I have seen in England!

3. Some equations from a Cardiology textbook.

526 Section IV Valvular Heart Disease

Doppler echocardiography is excellent for assessing the severity of aortic stenosis. By using the modified Bernoulli equation ($\Delta P = 4v^2$), a maximal instantaneous and mean aortic valve gradient can usually be derived from the continuous wave Doppler velocity across the aortic valve. However, accurate measurement of the aortic valve gradient requires a detailed, meticulous study with multiple sites of interrogation to ensure that the Doppler beam is parallel to the stenotic jet. In laboratories with experienced echocardiographers, the Doppler-derived aortic valve gradients are accurate and

The above "simplification" of the Bernoulli equation is also given in the textbook.

a. Verify the units of the pressure and velocity.
b. What simplifications of the Bernoulli equation give this?
c. Calculate the pressure change associated with blood in the left ventricle at 0 velocity that is accelerated to the common mean velocity of the Aorta. Does acceleration of the blood constitute a significant fraction of the pumping power of the heart?

Aortic valve gradients depend not only on the severity of obstruction but also on flow. In patients with low cardiac output, the stenosis may still be severe, with mean gradients less than 40 mm Hg. To overcome these problems, an aortic valve area (AVA) has been derived using the hydraulic equation of Gorlin and Gorlin. In the cardiac catheterization laboratory, the AVA is calculated from the pressure gradient and an independent measure of cardiac output.

$$AVA = \frac{1{,}000 \times CO}{44 \times SEP \times HR \times \sqrt{\Delta P}}$$

where CO = cardiac output, HR = heart rate, P = pressure difference across the valve, and SEP = systolic ejection period.

d. Use whatever you know and can find out to see if this equation matches with any of the fluid mechanical governing equations that we have derived in class.

Two-dimensional and Doppler echocardiography can also provide reliable estimations of aortic valve area by the continuity equation:

$$AVA = \frac{LVOT_{area} \times LVOT_{TVI}}{AV_{TVI}}$$

where AV = aortic valve flow velocity, LVOT = left ventricular outflow tract, and TVI = time-velocity integral.

Severe aortic stenosis can be diagnosed if a patient has clinical findings consistent with severe aortic stenosis, a mean gradient greater than 40 mm Hg, and AVA less than 1.0 cm^2 (Table 2).

Table 2. Criteria for Determining Severity of Aortic Stenosis

Severity	Mean gradient, mm Hg	Aortic valve area, cm^2
Mild	<25	>1.5
Moderate	25-40	1.0-1.5
Severe	>40	<1.0
Critical	>80	<0.7

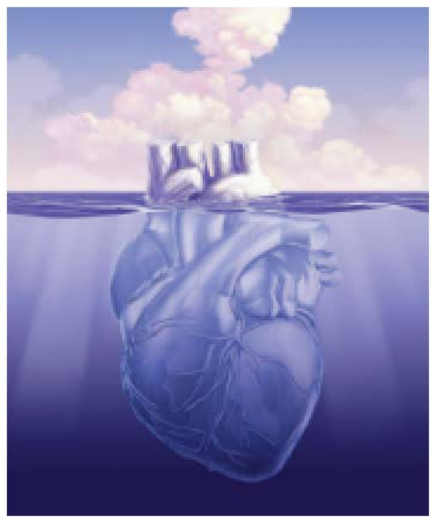
e. Likewise, can you make some progress with the interpretation of this equation?

Reference:

Mayo Clinic Cardiology

Concise Textbook

THIRD EDITION



Editors
Joseph G. Murphy, MD
Margaret A. Lloyd, MD